

CMS

Status Report

T. S. Virdee

Lehman Review, FNAL, Apr. 2000

General

Magnet and Infrastructure

Tracker

ECAL

HCAL

Muon

Trigger & DAQ

Physics Reconstruction and Selection

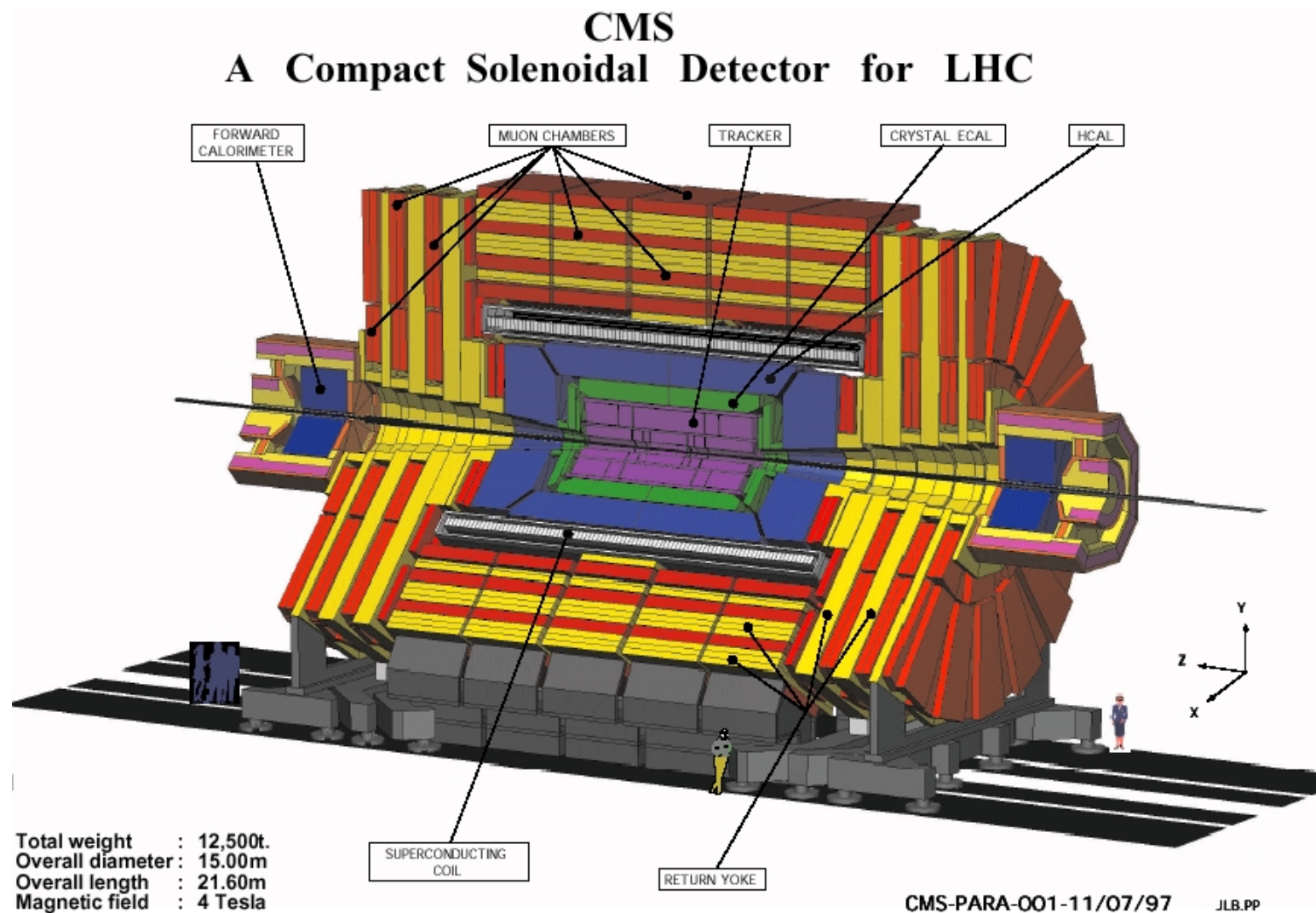
Computing

Animation

Compact Muon Solenoid



The CMS Detector

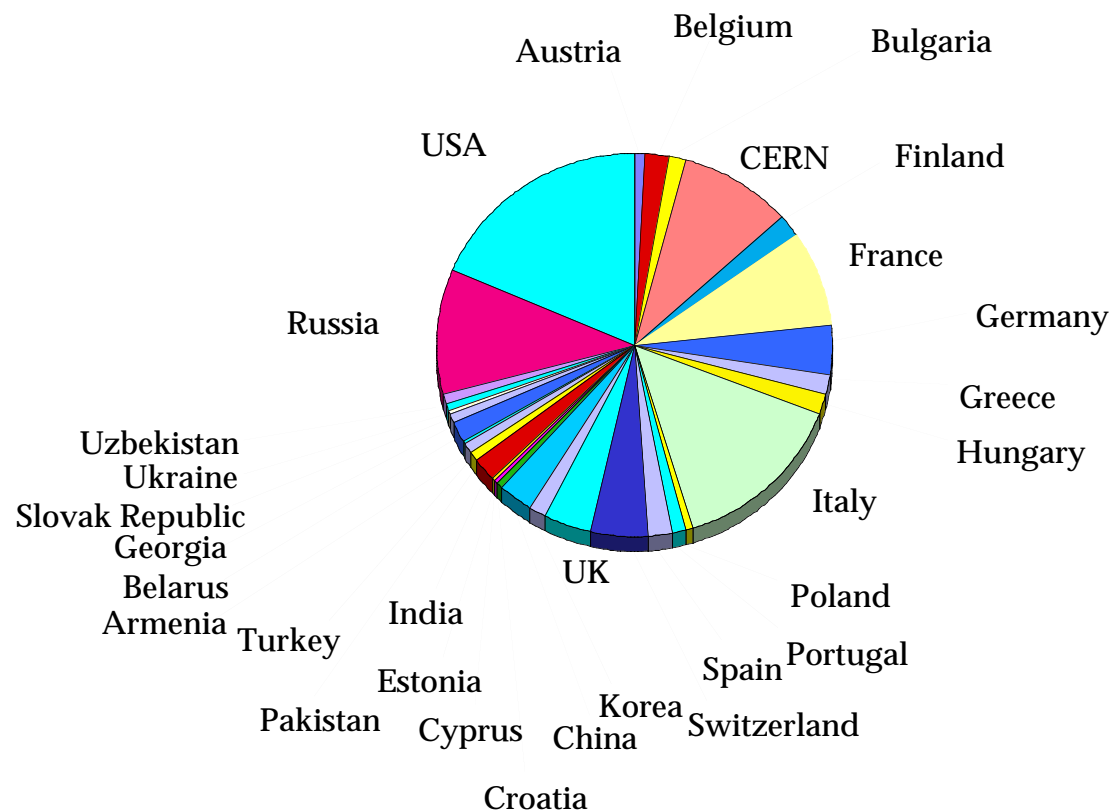




The CMS Collaboration

	Number of Laboratories
Member States	58
Non-Member States	47
USA	36
Total	141

	Number of scientists
Member States	1036
Non-Member States	421
USA	335
Total	1792

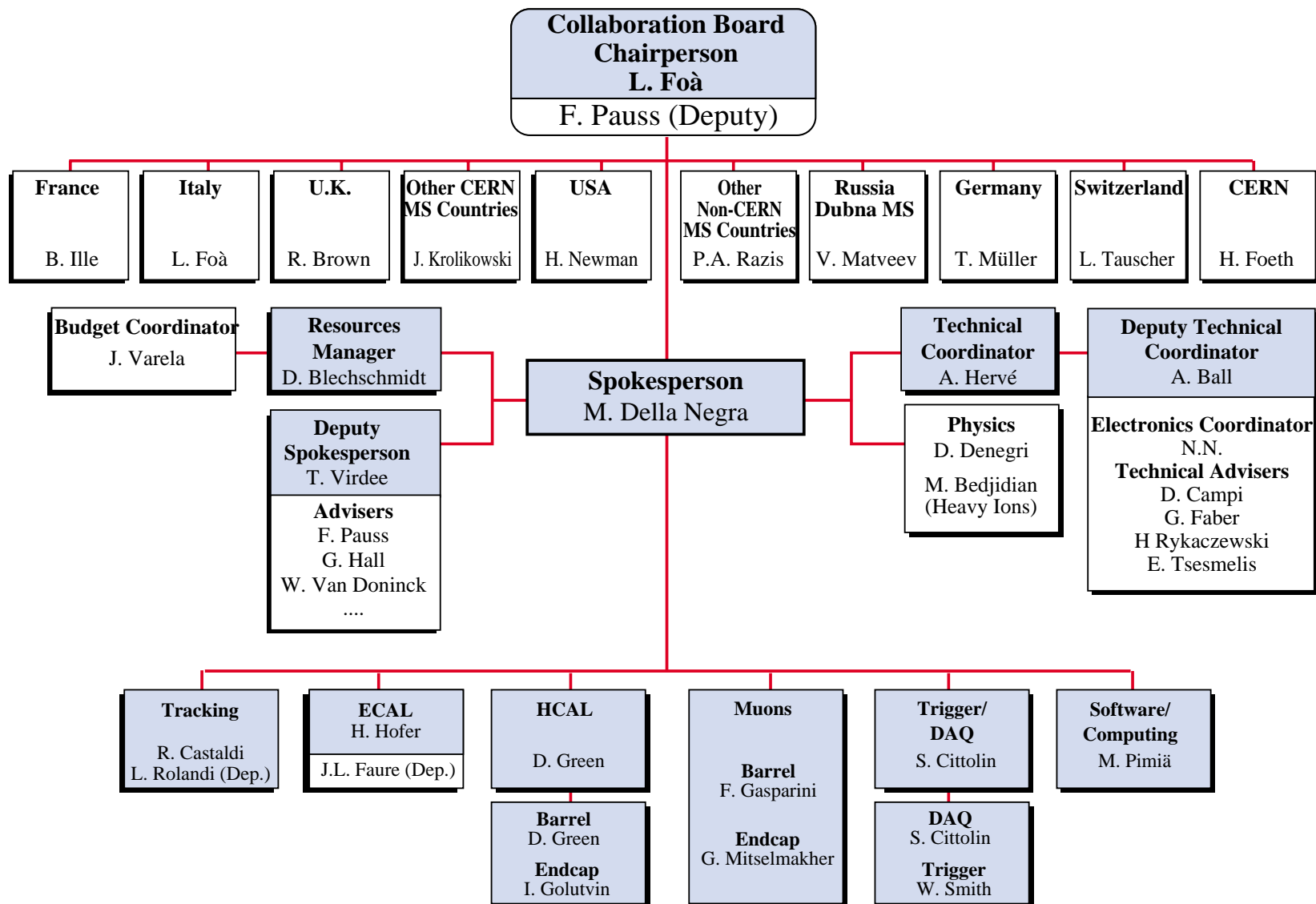


1792 Physicists & Engineers
31 Countries
141 Institutions

February, 21st, 2000/av
<http://cmsdoc.cern.ch/pictures/cmsorg/overview.html>



CMS Management Board and Steering Committee



Steering Committee

CMS Status/ Apr00

06 March 2000

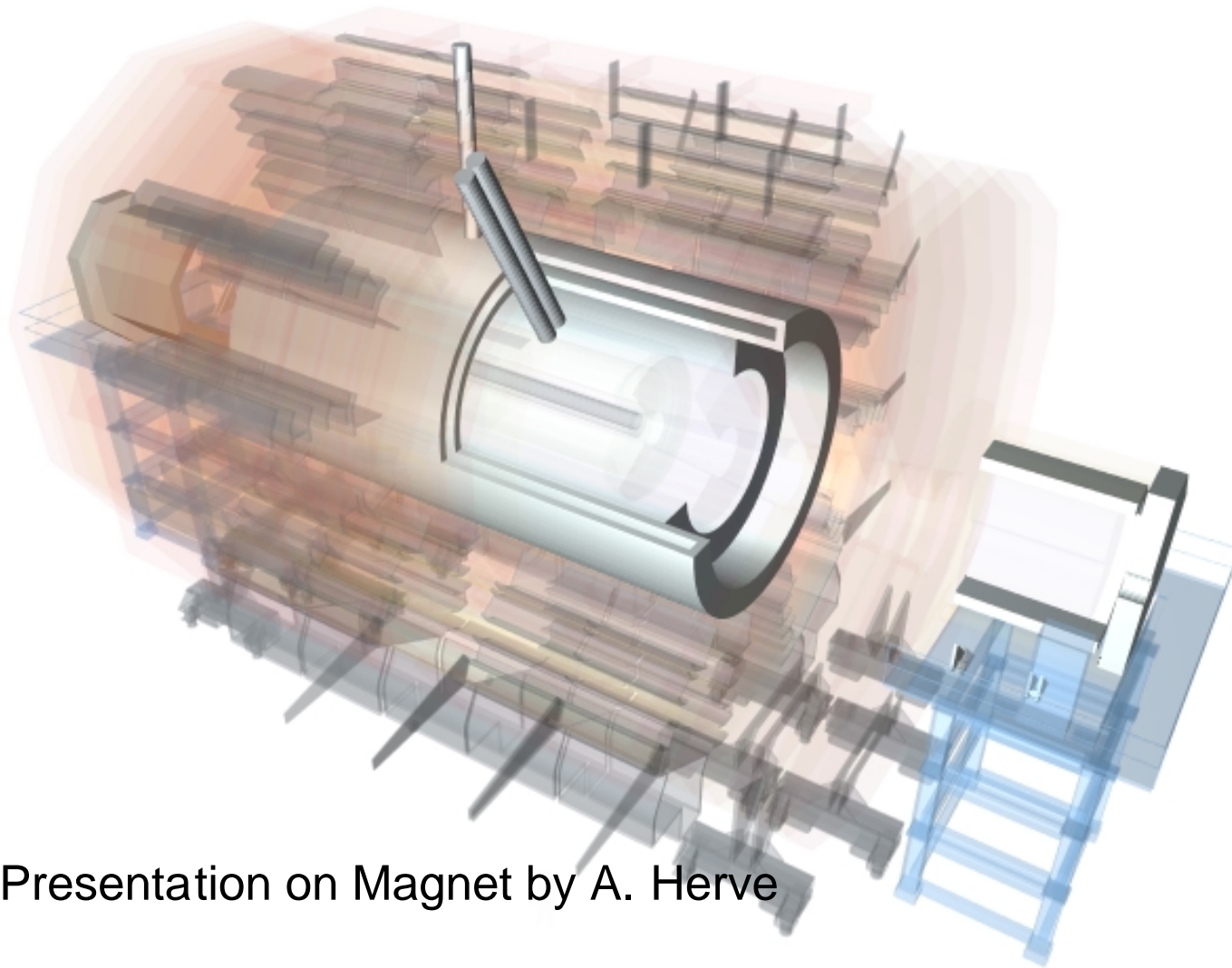


MoU Signatures

Austria	3.90	Italy	55.00	
Belgium	5.00	Korea	2.60	
Bulgaria	0.60	Pakistan	1.00	
CERN	85.20	Poland	3.00	
China	4.70	Portugal	2.00	
Croatia	0.28	RDMS-Russia	20.50	
Cyprus	0.60	RDMS-DMS	6.40	
Estonia	0.09	Spain	6.00	
Finland	5.00	Switzerland-ETHZ/Univ.	78.50	
France-CEA	5.60	Switzerland-PSI	8.50	
France-IN2P3	19.70	Taiwan		2.30
Germany	17.00	Turkey	1.00	
Greece	5.00	UK	9.10	
Hungary	1.00	USA-DOE	88.51	
India	4.40	USA-NSF	12.10	

Sum of Contributions	452.3
CMS Cost (Full Silicon Tracker)	455.9

1. Magnet and Infrastructure



Detailed Presentation on Magnet by A. Herve



Civil Engineering: Overview

- **The Status**

- The surface hall, SX5, has been delivered on time
- The civil engineering of the underground cavern, UX5, is delayed by 5 months compared with the contractual planning

- **Plans and milestones for 2000**

- Underground assembly schedule will be adjusted to allow completion of a working CMS detector for first LHC beams in 2005
- Surface hall, SX5, will be fitted-out by Jul 00 to allow magnet yoke assembly to start

- **Concerns**

- Further significant delays in civil engineering might compromise completion of a working detector for first beams in 2005



Magnet: Overview

- **The Status**

- All major contracts have been placed (84 MCHF ($\approx 70\%$) worth are under contract)
- The cost estimate of the magnet (121.9 MCHF) is maintained
- Magnet yoke construction is on schedule
- The SC Coil schedule, based now on contractual dates, exhibits a 5 month delay (sits in the shadow of the delay in civil engineering).

- **Plans and milestones for 2000**

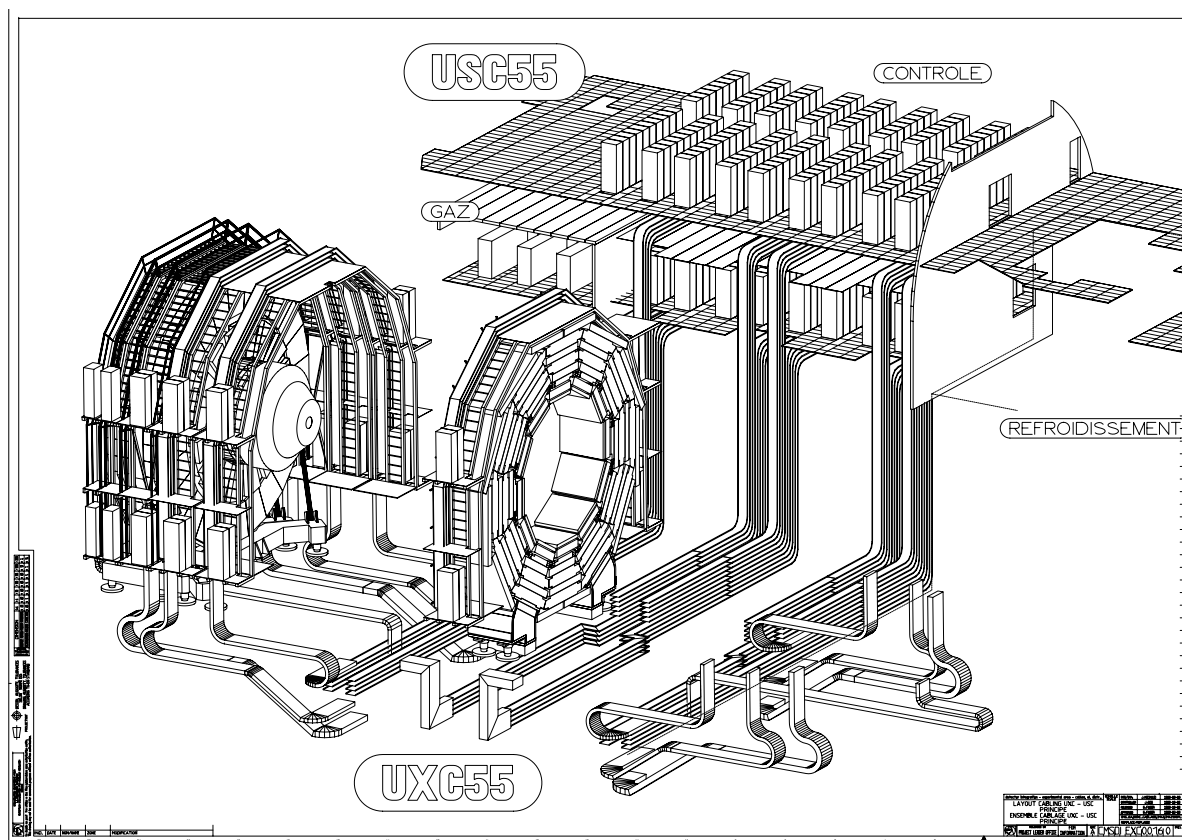
- Assembly of barrel yoke in surface hall, SX5, will start in July 00
- A 1 km demonstration length of conductor will be fabricated by Oct 00
- The winding line should be completed by Oct 00

- **Concerns**

- No major concerns



Integration: Services and Maintenance



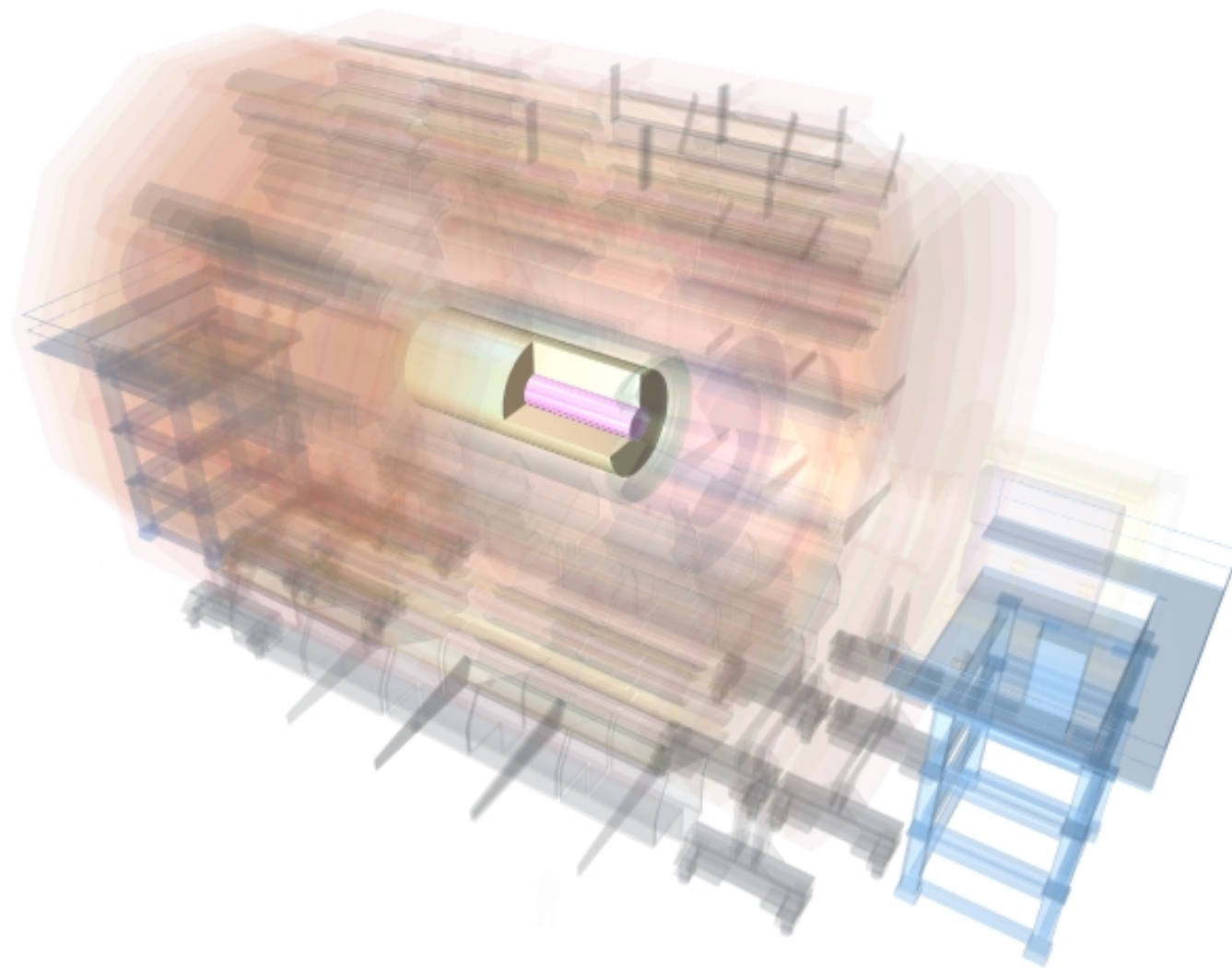
Targets for 2000:
Develop design of services
supplying CMS

cooling
inertion
gas
local racks
cable chains
TOTEM & Lumi. monitor

Develop maintenance
scenarios

long/short shutdowns
equipment required
sub-system task inter-
compatibility

2. Tracker





Tracker: Overview

- **The Status - Change to all-Si tracker** (subject to approval by the LHCC)
 - Redesign offers opportunity to improve the structure, simplify the services, increase modularity and improve maintainability
 - Results from mechanics prototypes built in 1999 can be exploited
 - Exceptionally good results from APV25 f.e. electronics (0.25 μ m technology)
 - Good progress with pixel detectors and electronics
- **Plans and milestones for 2000**
 - Procurement Readiness Review in June (procurement of pre-production sensors)
 - Establish automated module production in participating sites
 - Systems tests in beam
 - Study integration and maintenance scenarios
 - Prototypes of final size pixel sensors
- **Concerns**
 - Schedule: A detailed schedule has to be presented to the LHCC in May

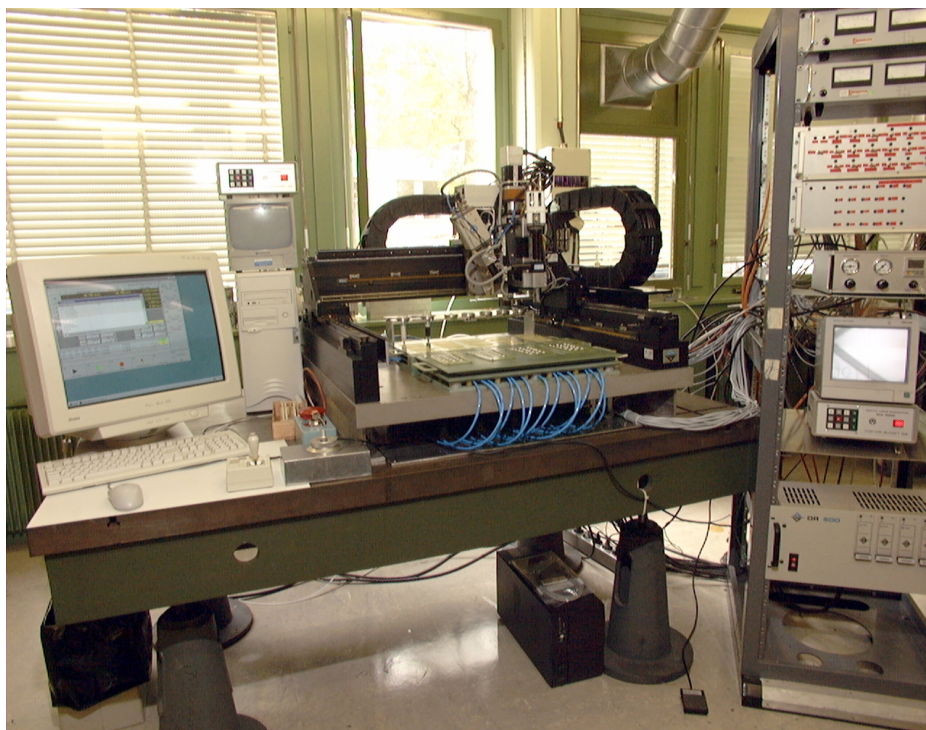


Tracker: technology decision

- Two stage Tracker in TDR (and MoU):
 - low luminosity (Phase I) and high luminosity (Phase II)
- TDR approved with an important Milestone on MSGC robustness
 - passed successfully at PSI in Nov 99
- All silicon layout studied as alternative solution
 - continuing decrease in cost of Silicon sensors
 - emergence of fabrication of larger area sensors on 6" wafers
 - possibility of streamlining module assembly through automation
 - availability of 0.25 μ m electronics with reduced cost and better performance
- CMS decided to move to a single technology - all-Si tracker
 - concentrate all efforts onto a reduced set of problems thus increasing the chances of on-time completion
 - propose a one stage full Silicon Tracker, with a performance similar to the one described in the TDR and within a cost ceiling of 77.5 MCHF.



Tracker: Automated Assembly



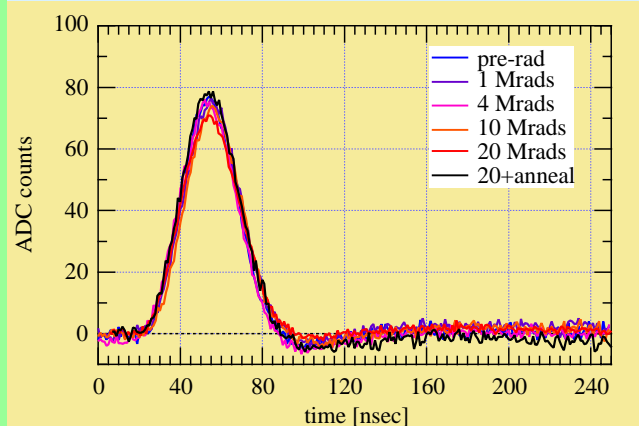
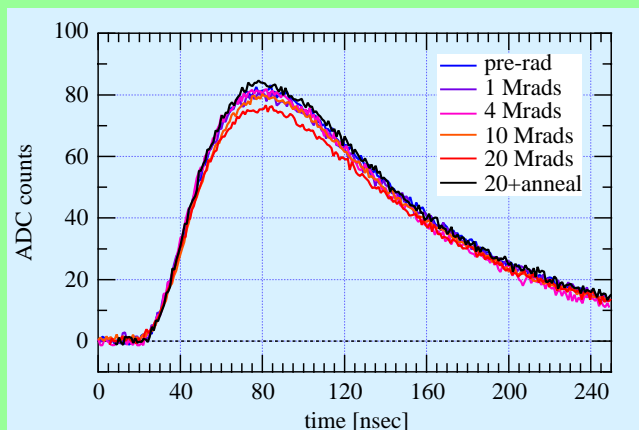
Construction Schedule

- Driven by module production
All modules can be produced in 2.5 yrs
6 robots for module assembly
12 Delvotec 6400 bonding machines
Factor 5 in over-capacity
- Sensors: 2 producers can each deliver all sensors in less than 2.5 yrs
- Electronics and mechanics can be produced in less than 2.5 years.



Tracker Front-end: APV25 Performance

Pulse shapes in operation modes 0 - 20Mrad



S/N in Deconvolution Mode

Inner Silicon

Strip length 12.5 cm, $t = 300 \mu\text{m}$

$S = 24000 - 15\%$ (rad. dam.)

$$N_{\text{APV6}} \approx 2000 \text{ e} \quad S/N_{\text{APV6}} \approx 10$$

$$N_{\text{APV25}} \approx 1600 \text{ e} \quad S/N_{\text{APV25}} \approx 13$$

Outer Silicon

Strip length 16.5 cm, $t = 400 \mu\text{m}$

$S = 31000 - 15\%$ (rad. dam.)

$$N_{\text{APV25}} \approx 1850 \text{ e} \quad S/N_{\text{APV25}} \approx 14$$

Other parameters:

linearity
cross-talk
stability
uniformity

all excellent

Yield is high &
chip smaller

= > lower cost

Power reduced

= > system gain

Buffers longer

= > no T1 risk



Pixel. Status of detector

1) **Pixel sensor received** (submitted Q2 99, by CSEM)

- Technique for bump bonding at 35 μ m established by PSI.
- Use of oxygenated silicon being explored

2) **Construction and tests of pixel minimodule (6 chips)**

- 6 pixel chips (22x30 pixels, reduced architecture chips) on hybrid.

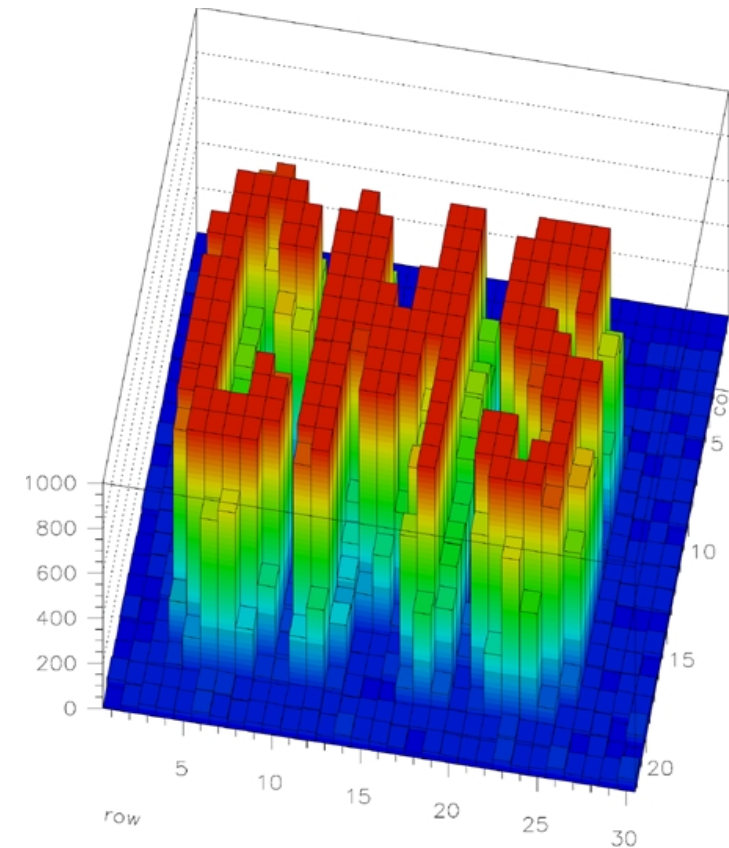
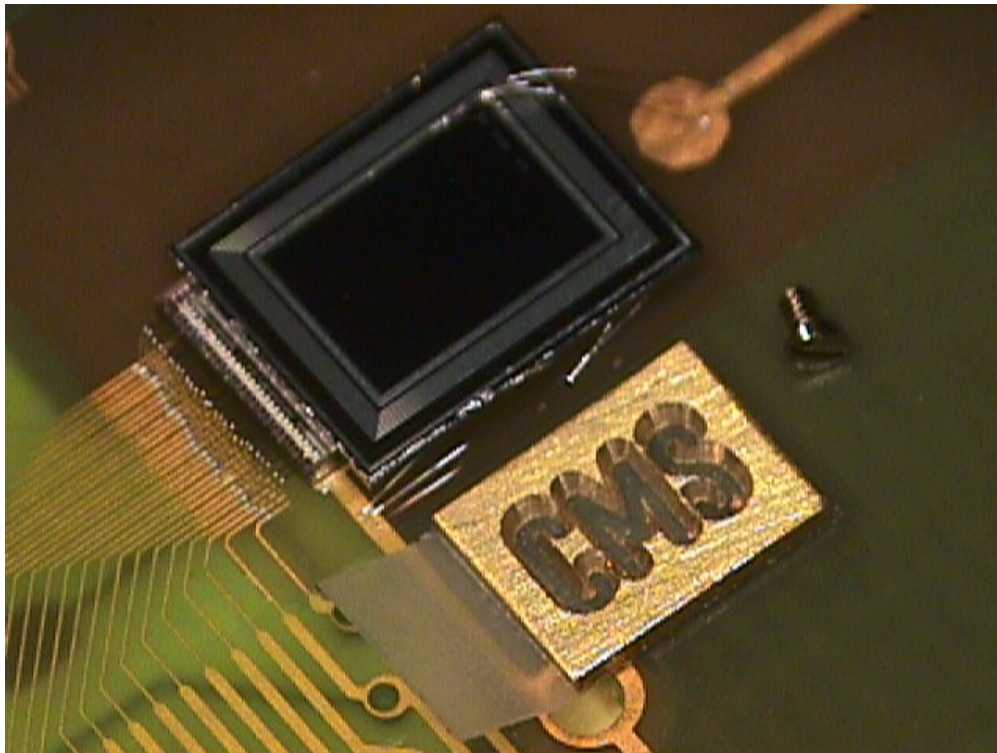
3) **Development of final Pixel ROC, 52x53 pixels** (ROC = Read Out Chip)

- Design of full architecture ROC on schedule. Target date for finished design of chip in DMILL technology Apr '00
- Translate design into Honeywell technology by Summer '00.



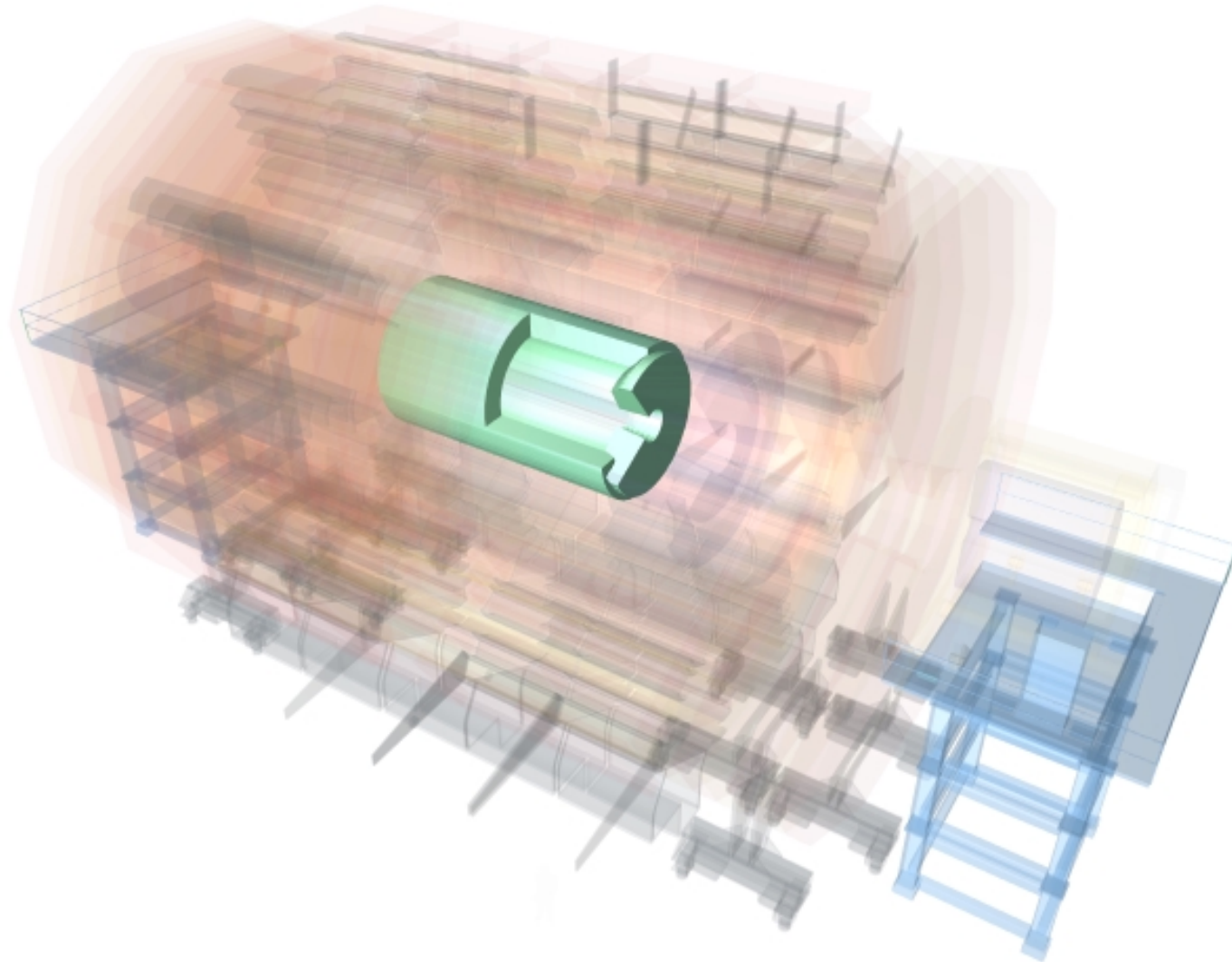
Pixel. Test of assembly

- Illumination with 14KeV x-rays (Rb)
- x-ray mask (500 μ m brass)



Lego plot of pixel hit rate

3. ECAL





ECAL: Overview

- **The Status**

- Russian crystals continue to be delivered on schedule. Reject $\leq 2\%$ (within target)
- Agreement reached in Russia for manufacture of 1/2 of barrel crystals (1.6 \$/cc)
- Delay of 9 months in crystal manufacturing in China. Price agreed (1.6 \$/cc)
- Two milestones missed (delay of ≈ 9 months) - errors in manufacturing
 - Module-0 - mechanical distortion of 'grid' that positions crystals
 - 500 electronics channel - very low yield (but ones received performed well)

- **Plans and milestones for 2000**

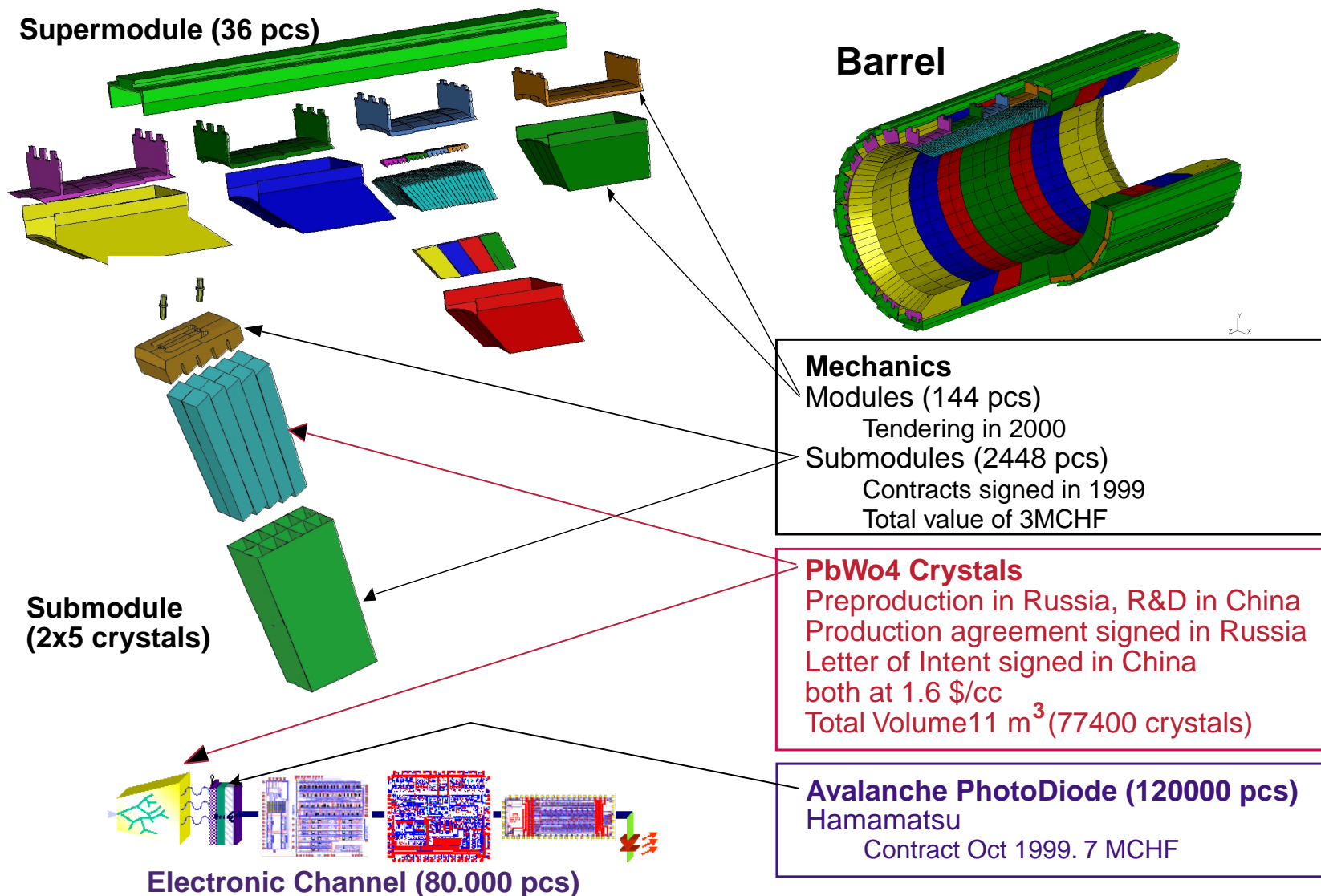
- Delayed milestones will be completed (not on critical path)
- Conclude crystal development in China (1000 crystals by end-00)
- Engineering Design Review of Endcap and Pre-shower system
- Electronic and Electrical System Review (Sept '00)

- **Concerns**

- The critical path item is crystals production
- Crystals are priced in \$/cc. Prevailing \$/SFr higher than used in Cost Book 9.



ECAL. EB Exploded View

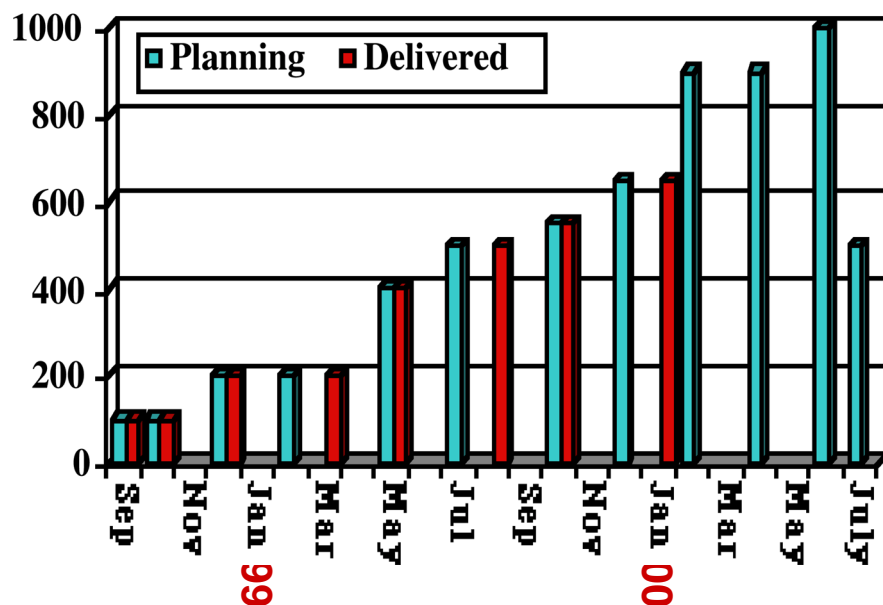




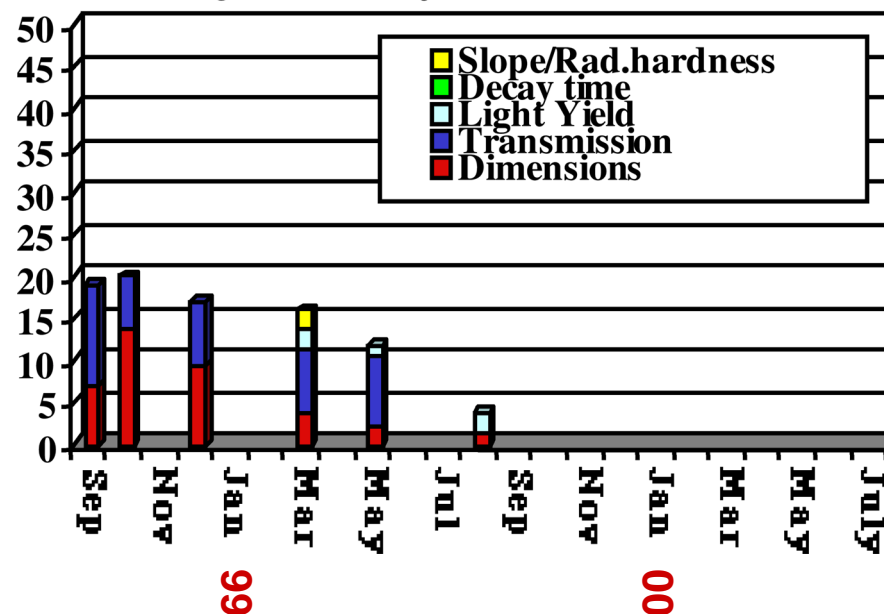
ECAL. Status of crystal delivery (Russia)

2700 crystals have been delivered (end Jan 00)

Delivered crystals



Rejected crystals (in %)

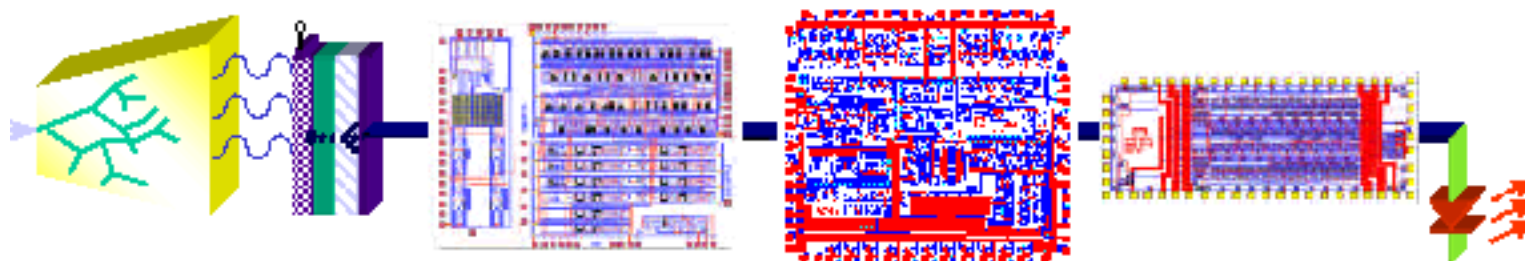


Schedule more or less followed, target yield achieved.
Agreement reached for production of half of the barrel crystals
End of development phase for endcap crystals



ECAL. Front-End chain

LIGHT to LIGHT



APD

FPPA

ADC

Serialiser

VCSEL

Hamamatsu
Contract placed
Start production
120k pieces

In Harris rad-hard
technology - processing
problems - low yield but
perform well

Analog Devices
OK

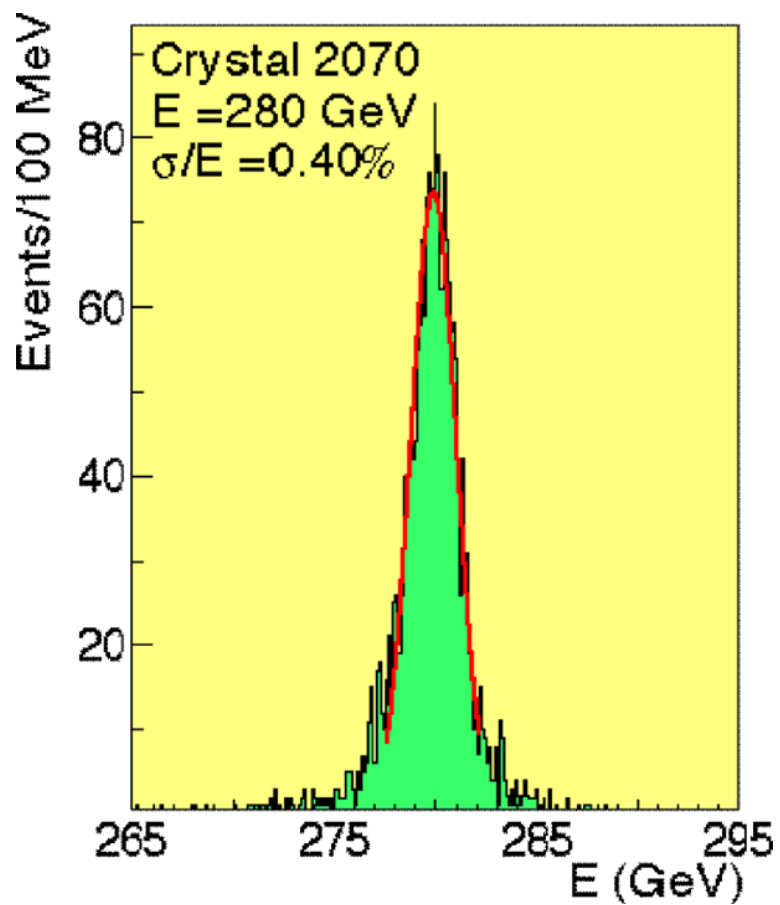
Problem of yield in
pilot production
In-spec samples work
Delay in pre-production

Discussing
packaging

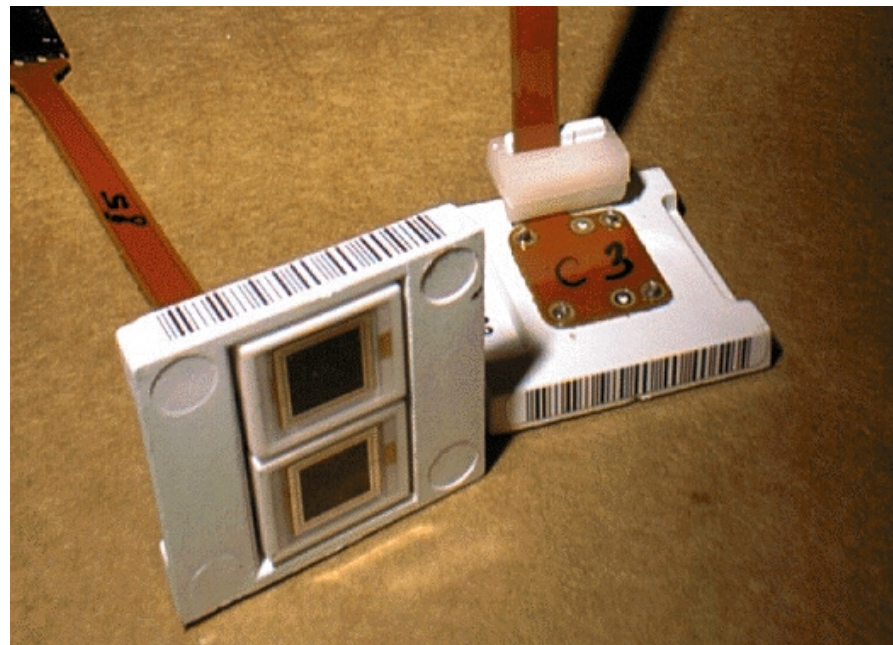
Foresee 2-400 channels test of whole chain in beam in Summer '00



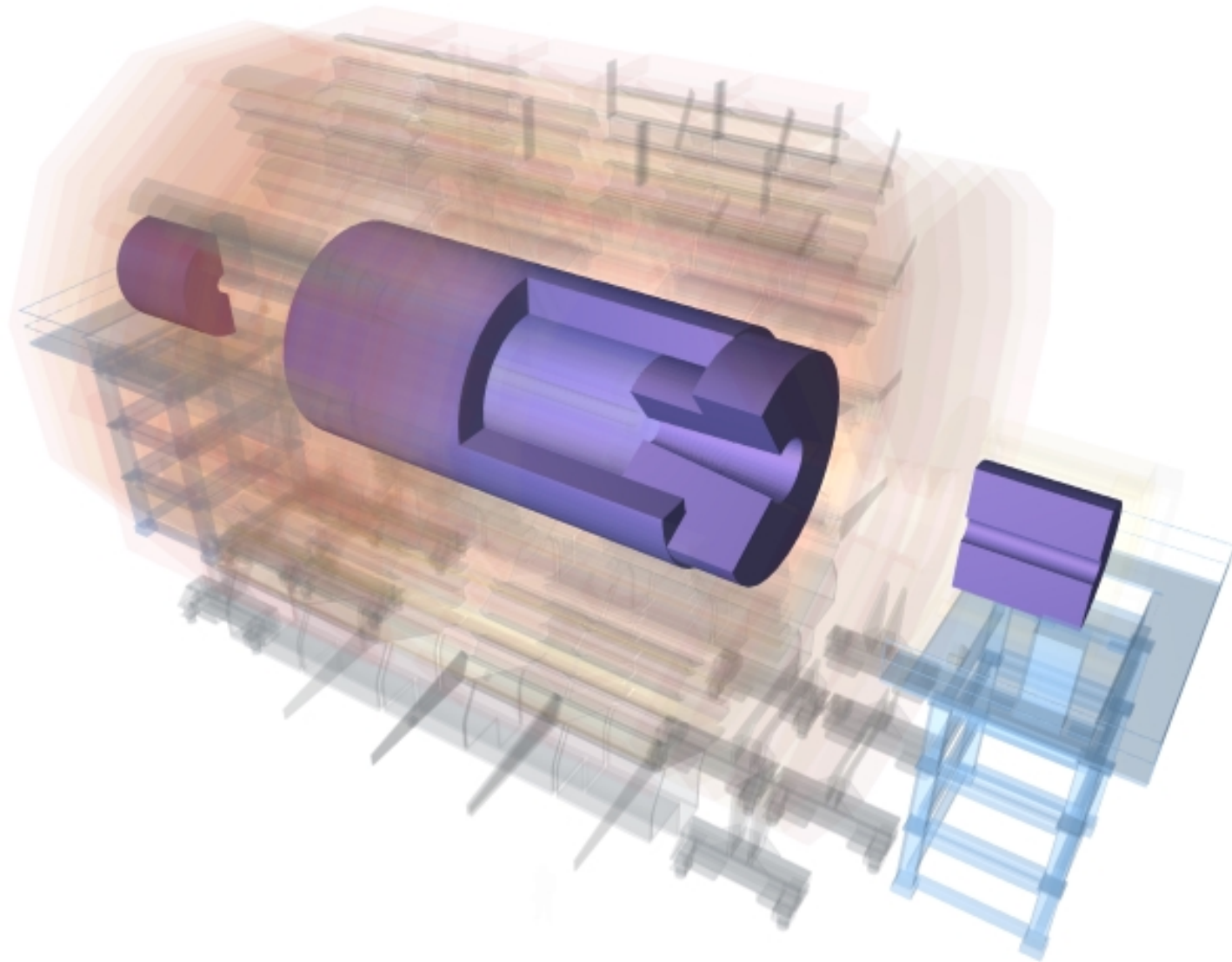
ECAL. Barrel 99 test beam results



Two APDs $5 \times 5 \text{ mm}^2$ surface area mounted in a supporting structure (capsule) glued at the rear of the crystal



4. HCAL





HCAL: Overview

- **The Status**

- Barrel (HB) absorber and optics manufacture is on schedule
- Endcap (HE) absorber is all under contract and manufacture has begun at MZOR
- HB and HE electronics design is significantly delayed (> 1 year) - action is being taken to ensure that this does not become a critical delay
- A prototype forward calorimeter (HF) 'brick' module was built and tested. HF engineering design has been transferred to FNAL - 'brick' \rightarrow 'sector' geometry.
- EDRs passed in 1999: HB - tooling & lifting fixtures, HO - Optics, HE - absorber.

- **Plans and milestones for 2000**

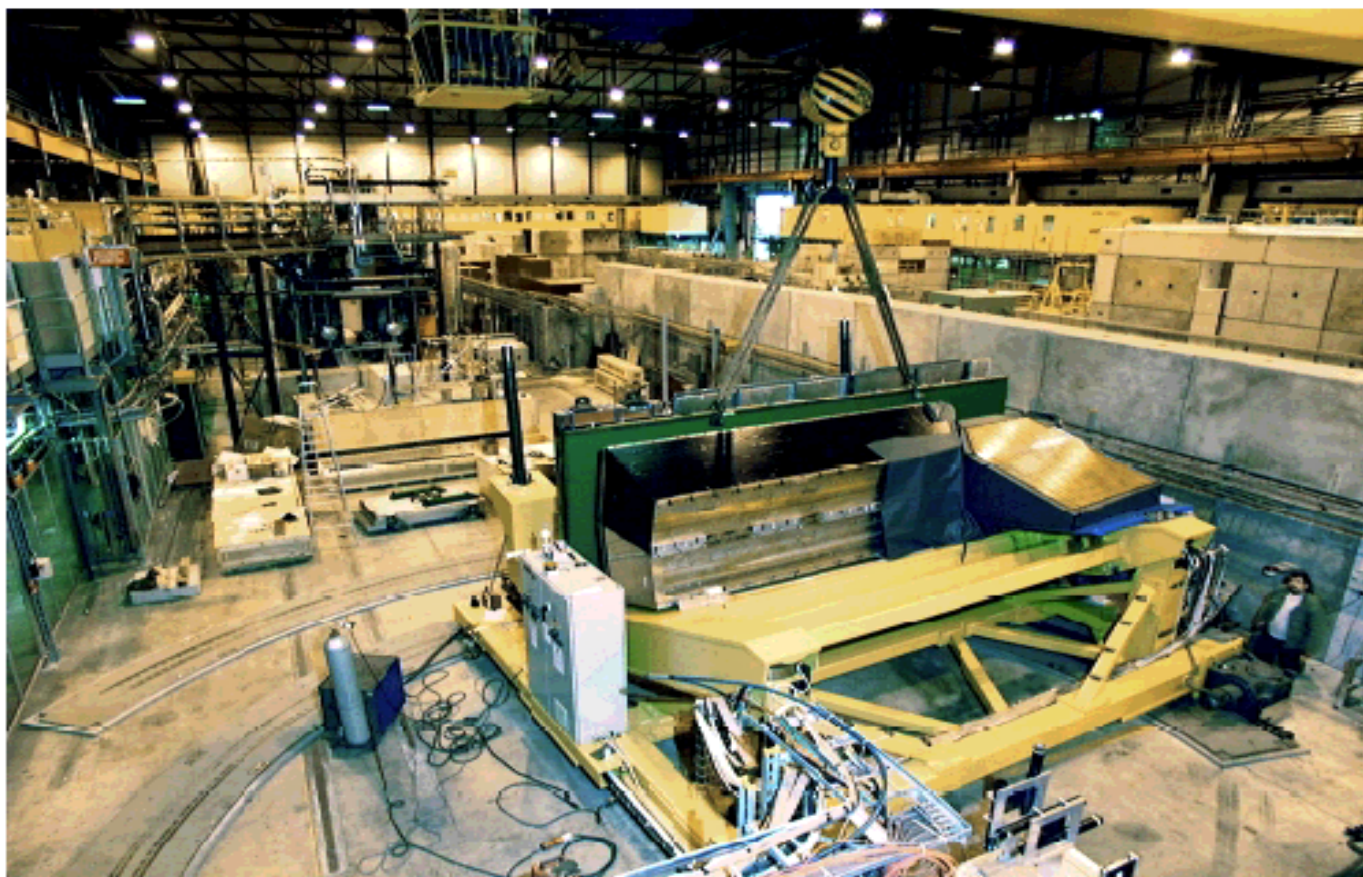
- Absorber and scintillator 'optics' package manufacture will continue
- A new HF prototype with sector geometry will be prepared for May '00

- **Concerns**

- Delays in the HB/HE electronics design must be kept off critical path



HCAL. H2 test beam



HB - PPP1

PPP2

HE - PPP

HO - PPP

HF - PPP

“ECAL”

**Comprehensive
test of CMS
calorimetry**



HCAL. HB - Finished Wedges



One half-barrel (18 wedges) will be delivered to CERN by end-00.



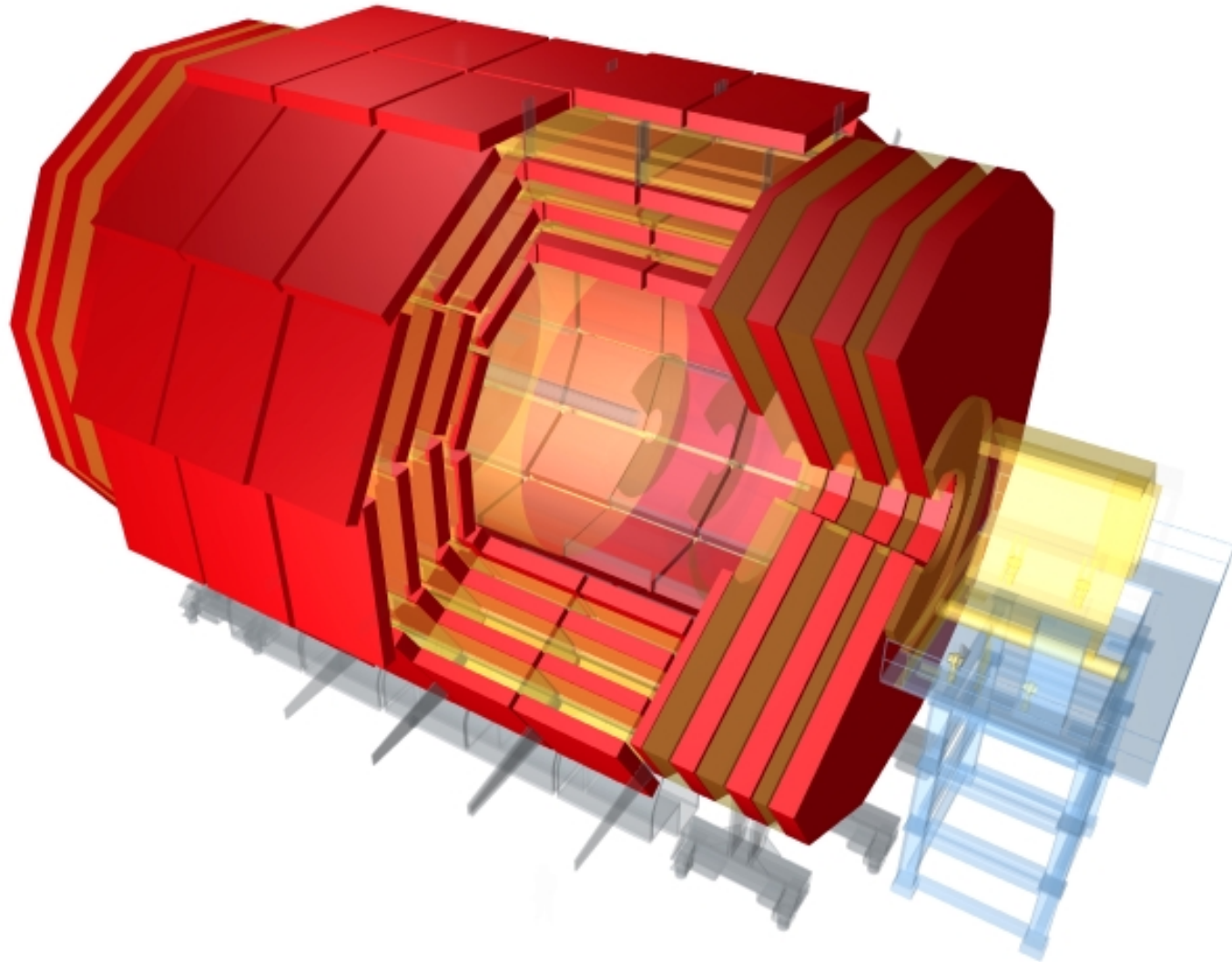
HCAL. HE - Plate machining

All the HE absorber is under contract

Brass plates procured in St Petersburg, machined in Minsk



5. Muon systems





Muon System: Overview

- **The Status**

- CSC manufacture underway in FNAL. Sites in Beijing and St Petersburg are in preparation
- Commissioning of MB drift tube assembly lines at Padua and Aachen taking longer
- MB site at Madrid building pre-production prototype MB2 without difficulty
- Assembly of barrel RPC gaps in industry will start soon. Bakelite manufacture started in February
- Results of a test of a minimal configuration of barrel alignment being analysed

- **Plans and milestones for 2000**

- Start-up of MB assembly lines in Padua and Aachen
- Transfer manufacture of electrode plates and I-beams to Dubna and Protvino resp
- ESRs for electronics mounted on DTs, and on-chamber electronics of CSCs
- Design of endcap RPCs (RE) will be completed
- EDR for alignment system

- **Concerns**

- End-00: Review rate of muon chambers manufacturing to check consistency with installation schedule



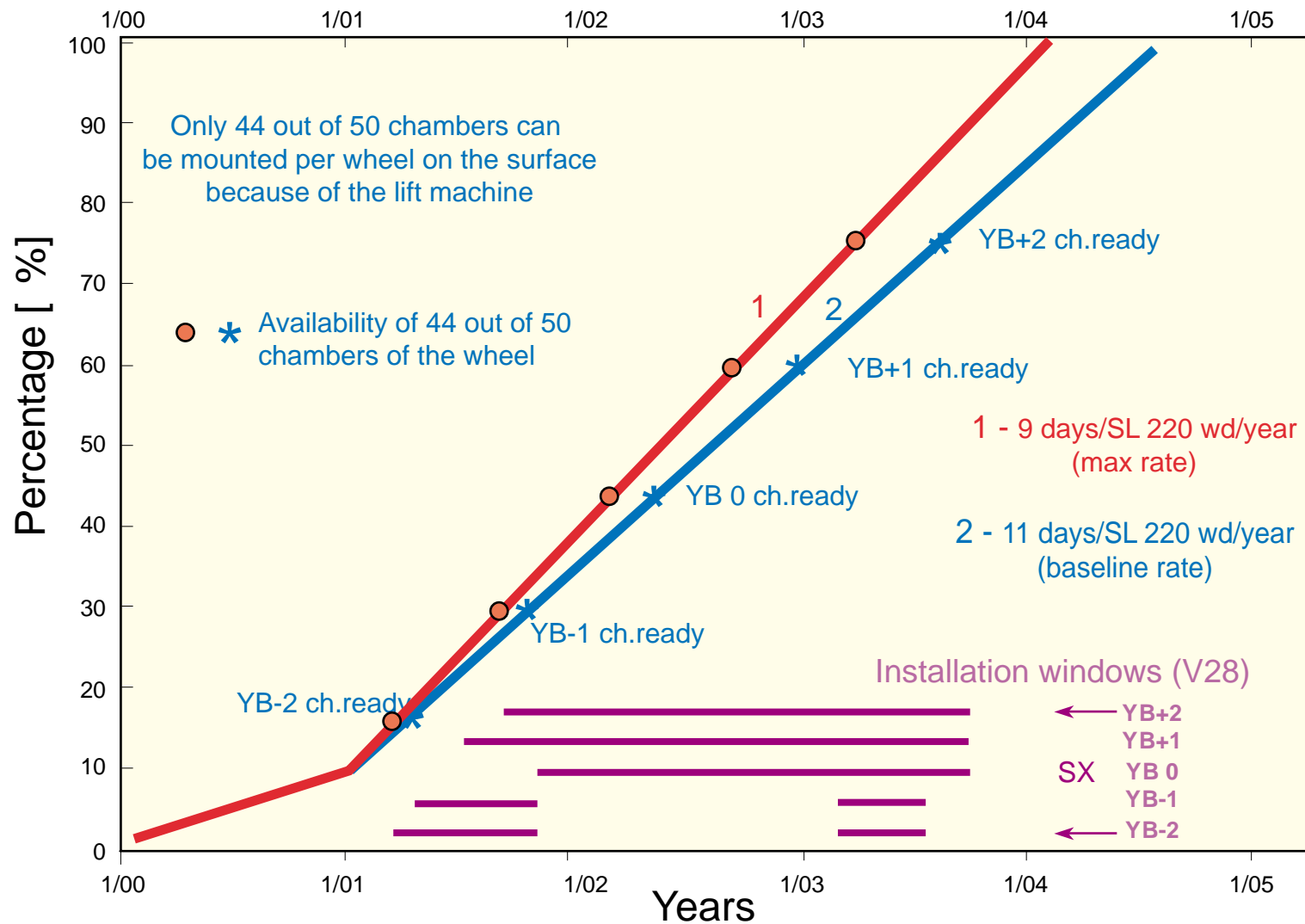
MB. DT Construction Status

assembly site	prod.lines	type of chamber (#)	ready	in production
Aachen	3	MB1 (70)	Jun 2000	Sep 2000
Legnaro	3	MB3 (70) MB4 (10)	Mar 2000	May 2000
Madrid	3	MB2 (70)	Jan 2000	May 2000
Torino	1	MB4 (30)	Oct 2000	Jan 2001
Volume production of plates (Torino → Dubna) Volume production of I-Beams (Bologna → Protvino) HV and Decoupling Boards (IHEP) Volume production of F-Ends Volume production of F-End Boards			Sep 2000 Jun 2000 Jan 2000 Jan 2000	Oct 2000 Oct 2000 Dec 1999 Mar 2000 Mar 2000

Preproduction in 2000: 2 MB1 in Aachen, 7 MB2 in Madrid, 5 MB3 in Legnaro



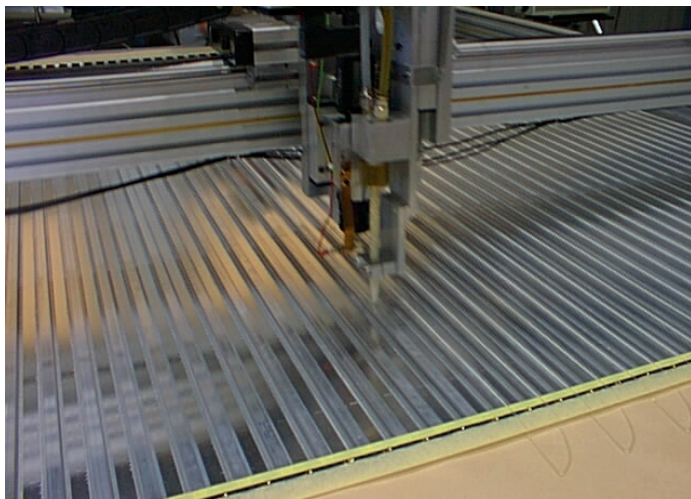
MB. DT Chamber production



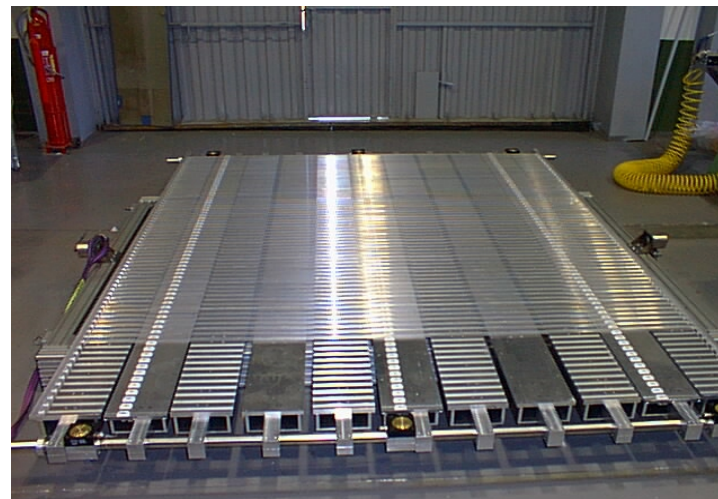
Michel_025



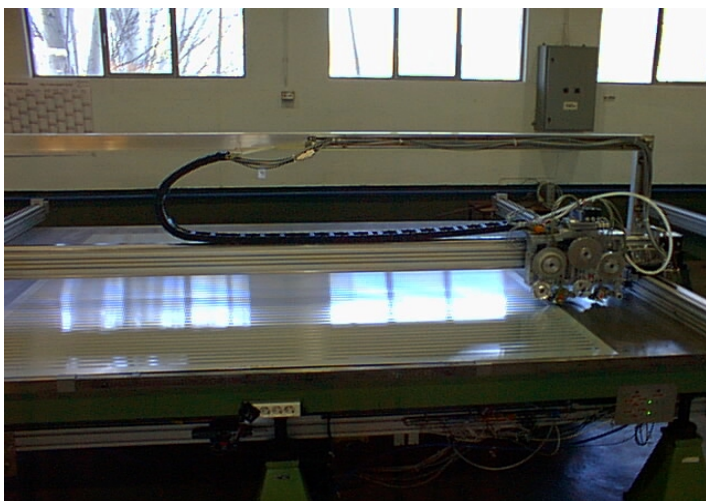
MB.Assembly sites



Ciemat/MB2:Glue on top of 1st layer of I-beams



Ciemat/MB2:1st layer of I-beams



Ciemat/MB2 plate with glued strips



Legnaro/Theta SL assembly table



Muon. RPC overview

Barrel

- Single gaps from industry
- RB1 assembled in China
- RB2 assembled in Italy
- RB3 assembled in Bulgaria
- RB4 assembled in Italy

The first RB2 chamber ready by April

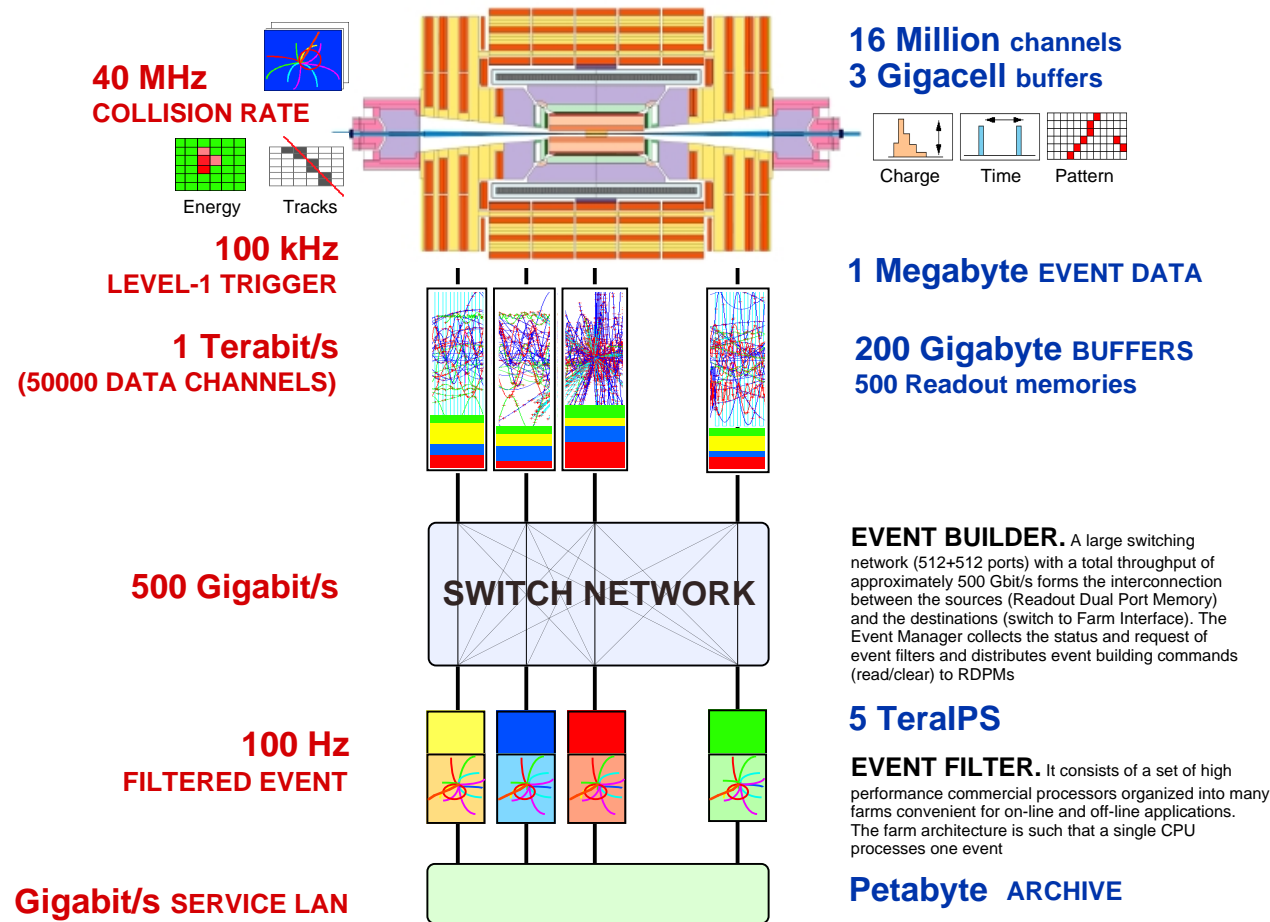
Forward

- Single gaps from Korea
- RE1 assembled in China
- RE n/1 assembled in Korea
- RB n/2 assembled in Pakistan
- RB n/3 assembled in Pakistan

The forward single gap will be built in Korea using Italian bakelite

Assembly of a forward sector in Korea and Pakistan in July

6. Trigger and data acquisition





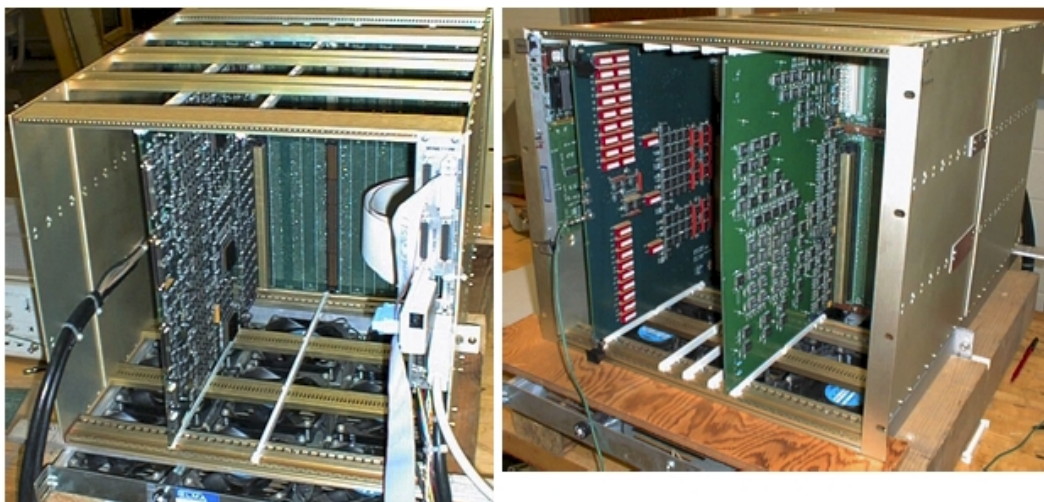
Level 1 Trigger Update

Level 1 Trigger TDR for November 2000

Recent improvements in Calorimeter trigger:

Jet algorithm & Tau-Trigger

New design of jet algorithm with sharper efficiency turn-on and tau-jet bit for narrow jets based on 4x4 regions sums into 12x12 region jets with sliding windows logic.



Prototype Crate with

- 160 MHz Backplane: timing & signals excellent
- Proto. Receiver Card (rear): VME, sharing, Adder ASICs checked
- Proto. Clock Card (front): Clocking checked
- Proto. Electron ID Card (front): VME, dataflow, timing checked



Muon Trigger Progress

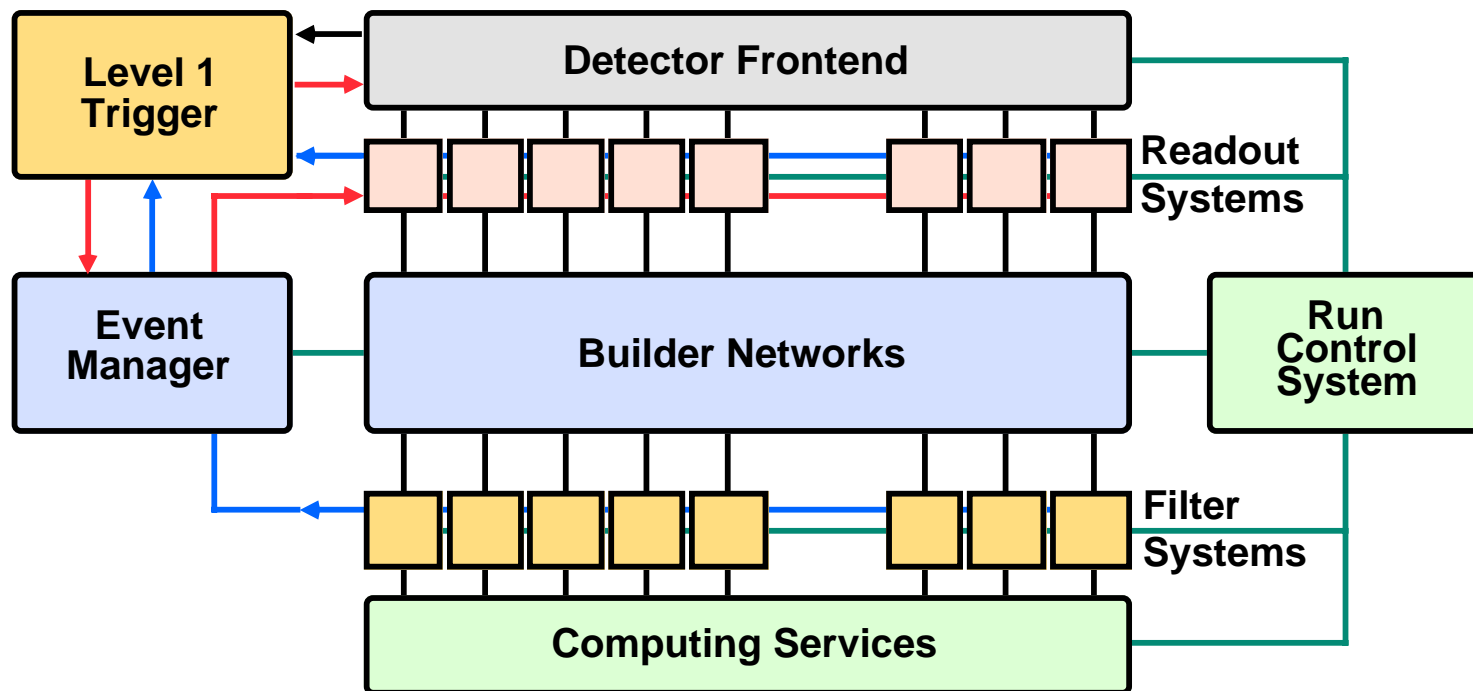
Drift Tubes: 2nd Prototype Bunch & Track Identifier and Control Board tested with cosmics, simulation, neutrons. Beam tests with track Correlator show clean triggers with 0.5 mm position and 2 degree angle resolution with 95% efficiency. Track-finder design is mature.

RPC: Front end, sorter, and Pattern Logic chips have been tested. Link technology verified (including radiation tolerance). Optical fiber multiplexing simulated.

CSC: Prototype Comparators, Anode & Cathode Local Charged Track & Motherboard beam test meet performance requirements. Design to send RPC data to CSC's to kill ghosts developed. Muon Port Card, Sector Receiver, Sector Processor and Sorter prototypes under design.



DAQ main parameters

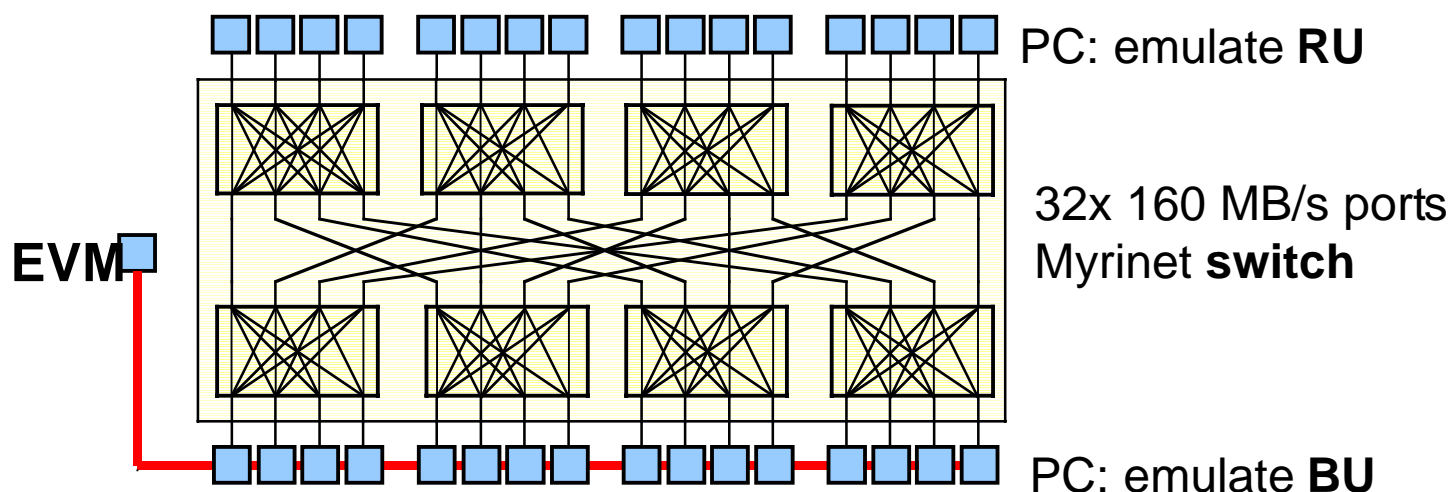


Collision rate	40 MHz	I-O units bandwidth (512+512)	400 MByte/s
LV1 Maximum trigger rate	100 kHz	Builder network (512x512 port)	≥ 500 Gbit/s
Average event size	≈ 1 Mbyte	Event filter computing power	$\approx 5 \cdot 10^6$ MIPS
Data production	\approx Tbyte/day	High Level Trigger acceptance	1 - 10 %
Event Flow Control	$\approx 10^6$ Mssg/s	Overall dead time	$\leq 2\%$

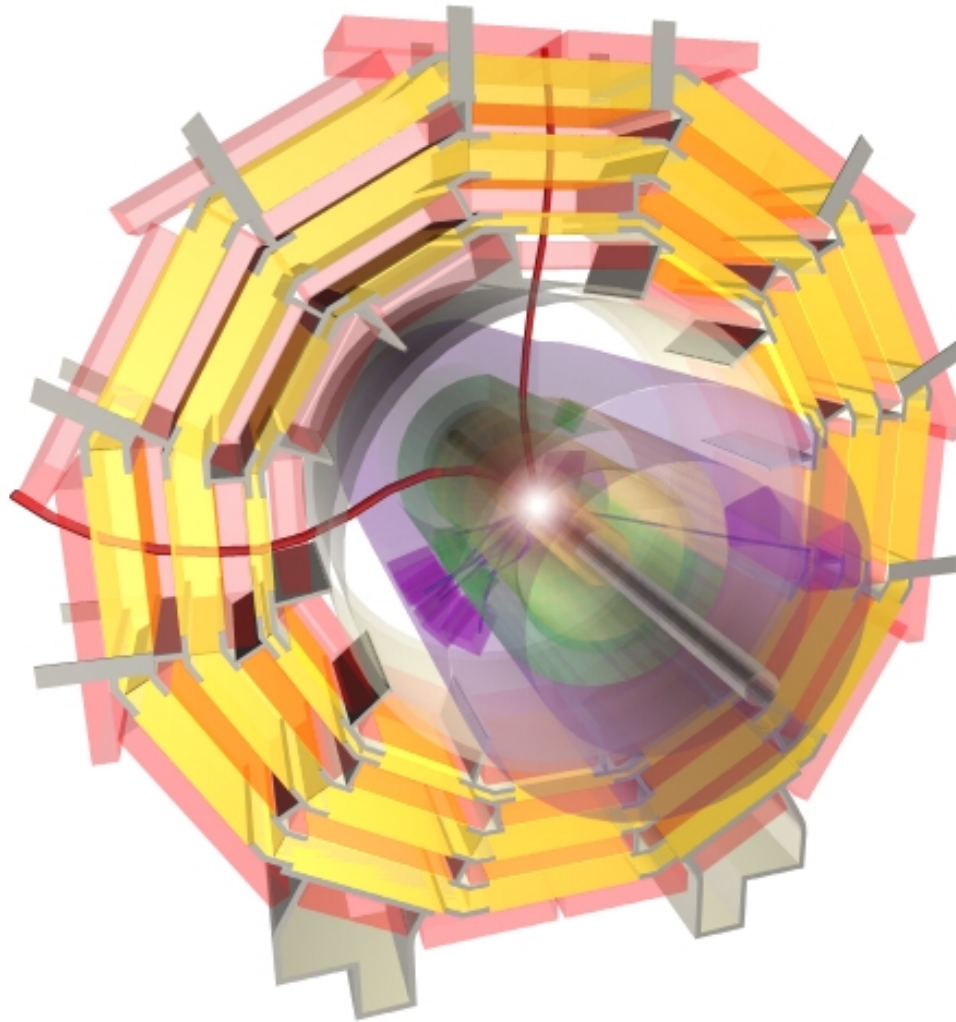


DAQ. Myrinet evaluation 1999

- Event builder demonstrator 16x16 based on Myrinet multistage switch and Linux PCs established.
- Measured event building performance: Achieve about 60 kHz trigger rate or 120 Mbyte/s per node (almost 2 Gbyte/s aggregate) for nominal event fragment sizes with average and RMS of 2 kbyte.
- That is, **today, only a factor two off** from CMS needs.
- Measurements provide parameters for simulation of large scale (512x512) systems. **DAQ TDR in November 2001**



7. Physics Reconstruction and Selection (PRS)





High Level Trigger

- Basic Job: 100 kHz to 100 Hz (keeping physics)
- After hardware Level-1 assume two steps:
 - Level-2 only uses calorimeter & muon data
 - Read only 25% of the data and get rejection factor A_2 .
 - Level-3 uses tracker data as well
 - Provides final rejection factor $A_3^* A_2 = 1/1000$
- New CMS Project: Physics Reconstruction & Selection (PRS):
 - Four groups established in April 99:
 - b/τ (vertex), Electron/Photon, Jet/Missing E_T , Muons
 - Charge: evaluate full chain (from Level-1 to offline) of physics selection. First priority (till end 2000): HLT.
- CMS decided not to submit Physics TDR, but to push with the deployment of OO software
 - First (DAQ) milestone: HLT prototype 1 - Nov '99
 - Partially met because of C++ hill/mountain
 - **HLT milestone delayed to July '00**



e Level-2 rate (preliminary)

Single electrons (barrel only)

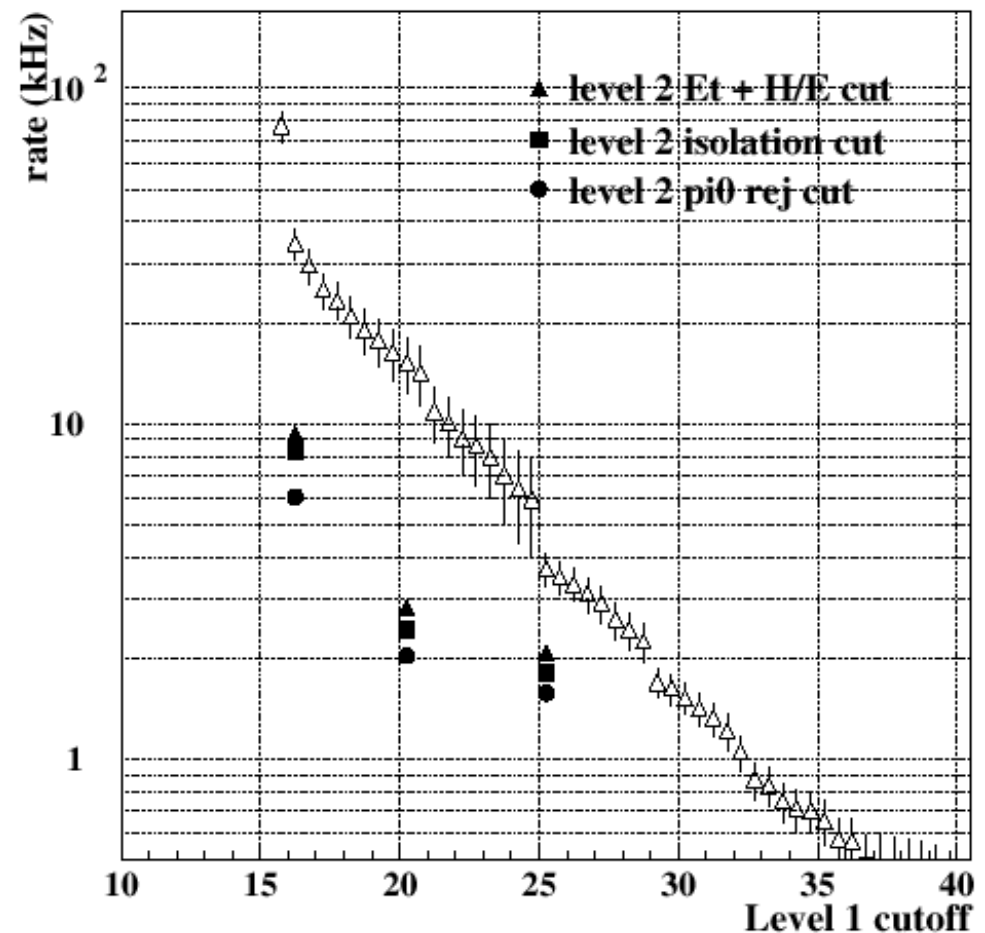
Full Geant simulation of QCD jets.

Implemented in ORCA3: Level-1
trigger simulation.

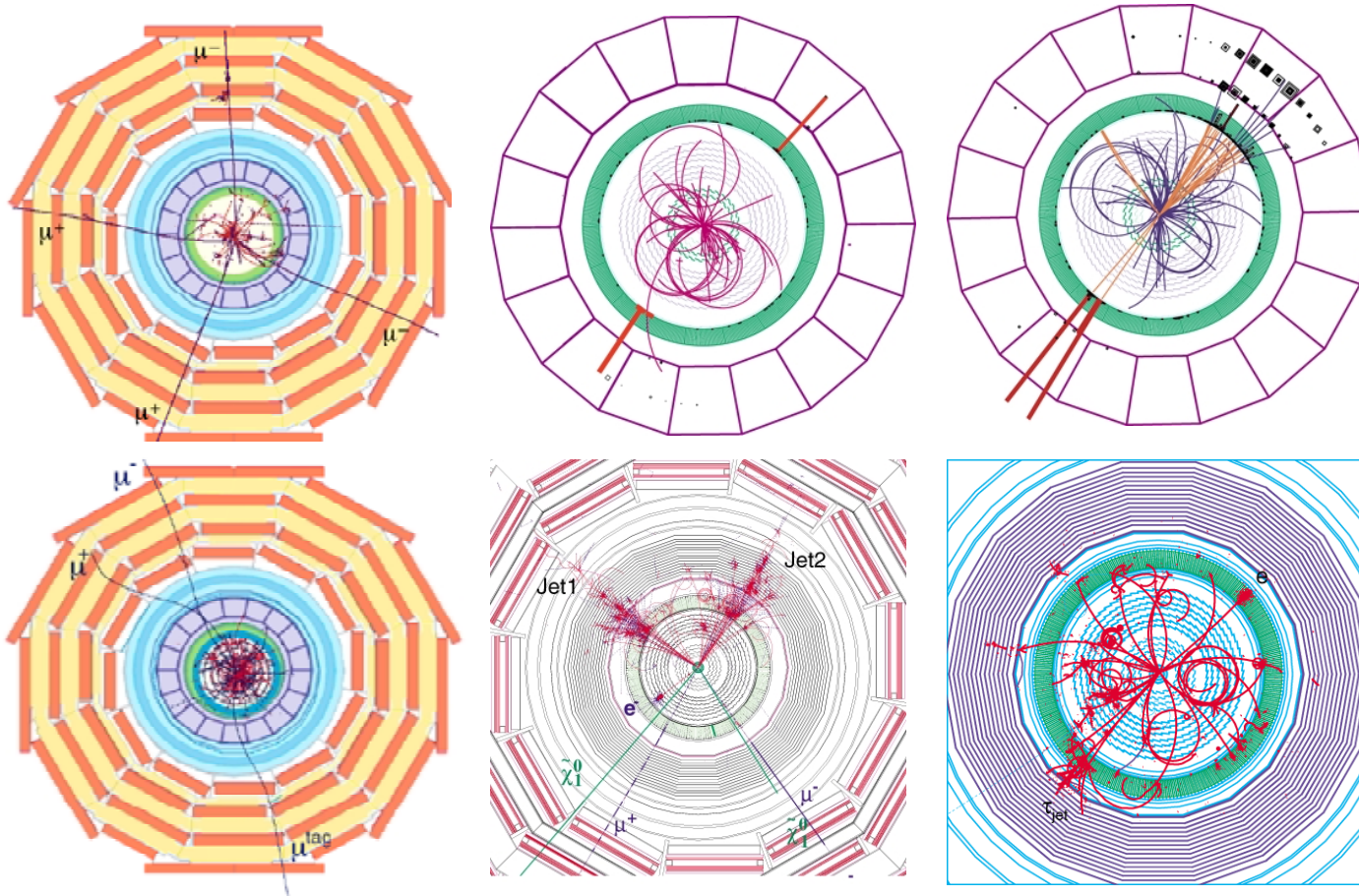
Full calorimeter response
including high luminosity pile-up.

Level-2 rejection factor: in 3-10
range

Good efficiency: 94%



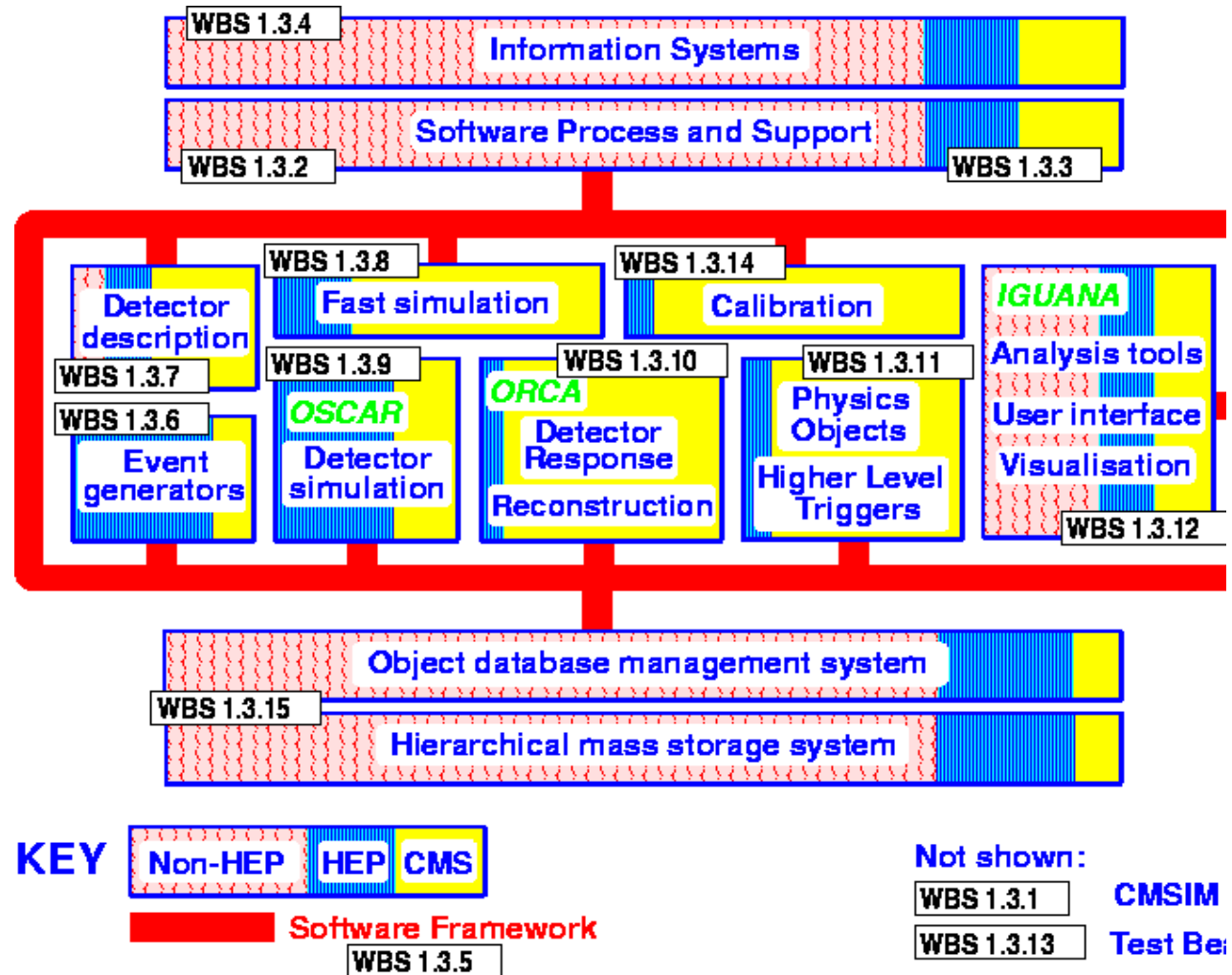
8. Software/Computing





Software tasks

- 1.1 Project Management
- 1.2 Computing
- 1.3 Software
 - 1.3.1 CMSIM
 - 1.3.2 Software Process
 - 1.3.3 Software Support
 - 1.3.4 Info. Systems
 - 1.3.5 CARF
 - 1.3.6 Event Generators
 - 1.3.7 Det. Description
 - 1.3.8 Fast Simulation
 - 1.3.9 OSCAR
 - 1.3.10 ORCA
 - 1.3.11 **OBSOLETE**
(was *POR / HLT*)
 - 1.3.12 User Analysis
Environment
 - 1.3.13 Test Beam
 - 1.3.14 Calibration
 - 1.3.15 ODBMS





HLT and Software/Computing Plans

Tie ORCA project to concrete experimental requirement, **the HLT verification**, provides a powerful focus;

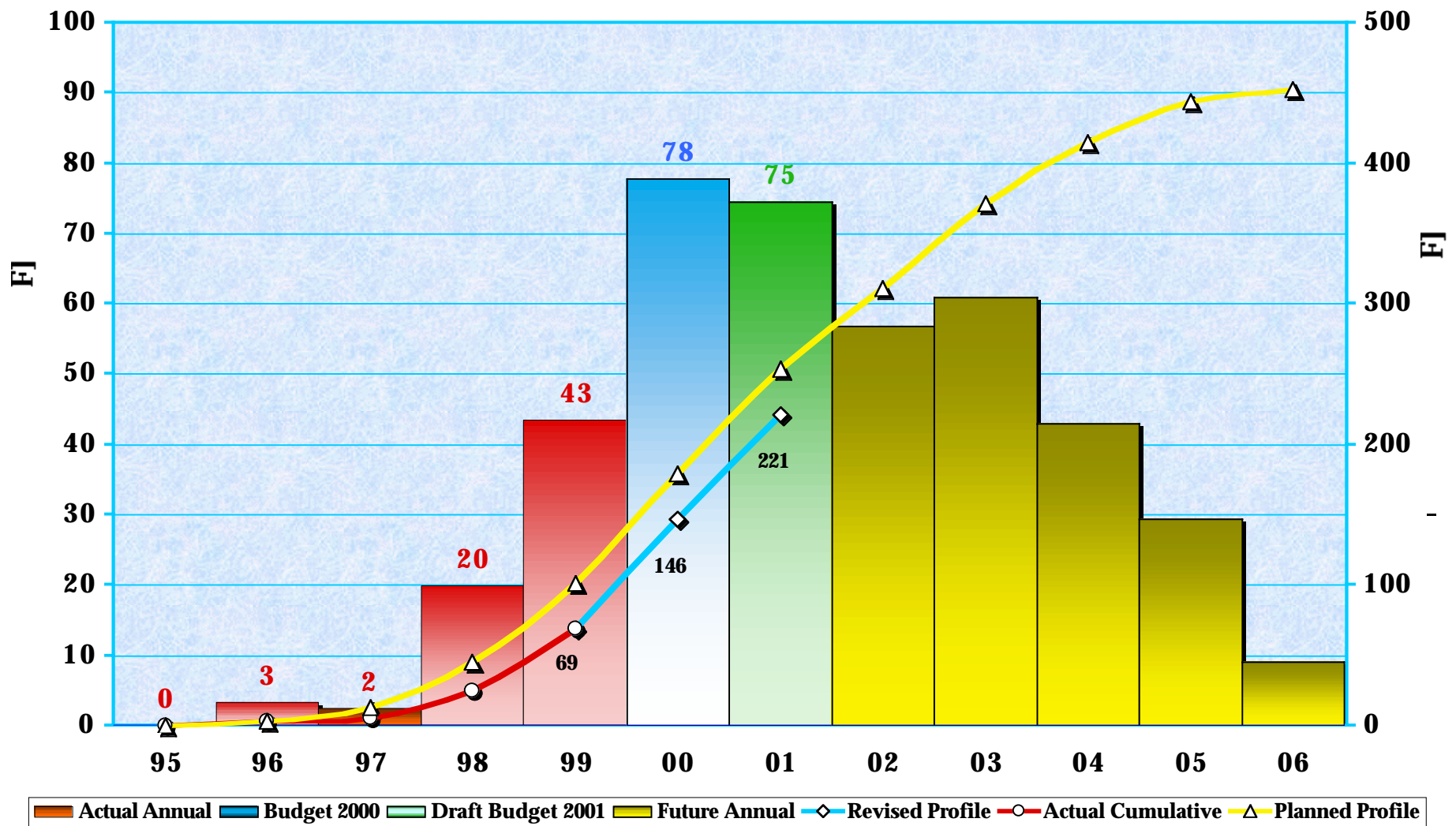
CMS Computing and Software model is designed to meet LHC requirements; use **ORCA and HLT** to study this model in depth

This HLT study is the first in a series of increasingly complex **“mock-data challenges”**

HLT L2 (calo+muon) reduction	July	2000
HLT L3 (tracker) reduction	Fall	2000
Trigger TDR	End	2000
DAQ TDR	End	2001
Computing TDR		2002
Physics TDR		2003
20% Mock-Data Challenge		2004



Payments for CMS Construction





Conclusions

Good progress has been made in 1999.

The Magnet schedule and cost are now well established.

Construction of HCAL is well underway, on schedule and within cost estimate (to watch - the electronics).

Pre-construction of Muon chambers in 2000 (to watch - rate of chamber production).

ECAL crystal production is under way in Russia. Cost of crystals (in terms of \$) and photosensors within cost estimate (to watch - crystals production).

Tracker - change to all-Si sensors, impressive results using 0.25 μm technology.

CMS is making plans for a 'working' CMS detector to be ready for first LHC beams in 2005, taking into account technical and financial constraints.